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(54) **POWER CONVERTER HAVING IMPROVED COOLING**

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See application file for complete search history.

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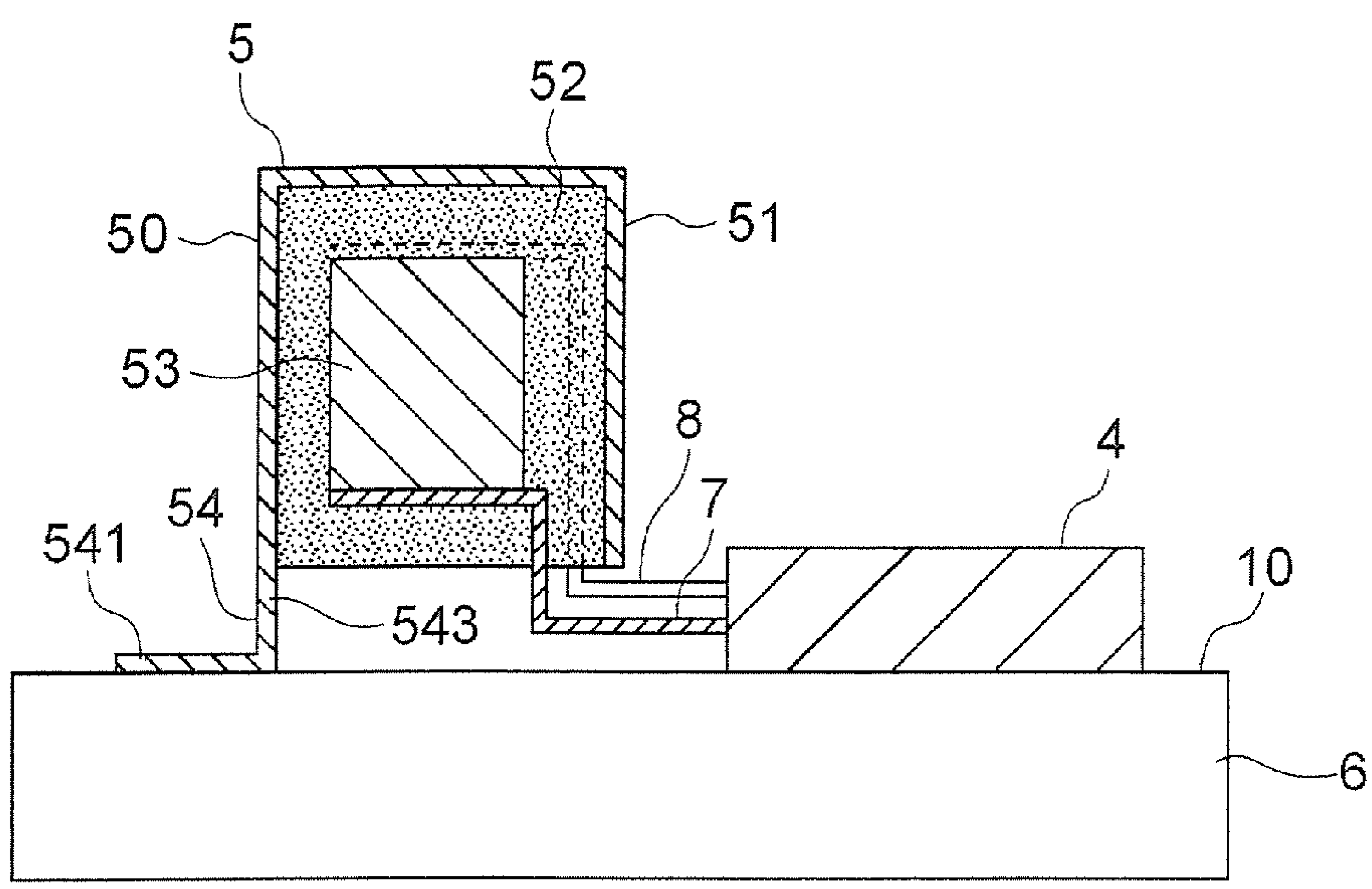
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC; Richard C. Turner

(57) **ABSTRACT**

Provided is a power converter which enables improved performance, and allows each of a semiconductor module and a capacitor module to be more reliably cooled. In a power converter, a capacitor module includes a capacitor module main body facing a cooling surface of a cooler, while being apart from the cooling surface, and a heat conductive member provided in the capacitor module main body. The capacitor module main body is connected to a semiconductor module via an N-side bus bar and a P-side bus bar. A heat radiation portion of the heat conductive member is thermally connected to the cooling surface at a position more distant from the semiconductor module than an end portion of the capacitor module main body which is closer to the semiconductor module.

5 Claims, 5 Drawing Sheets



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H01G 4/224	(2006.01)
H01L 23/373	(2006.01)
H01L 23/473	(2006.01)
H02M 7/00	(2006.01)
H02M 7/48	(2007.01)

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CPC ***H01L 23/473*** (2013.01); ***H02M 7/003*** (2013.01); ***H02M 7/48*** (2013.01); ***H05K 7/209*** (2013.01)

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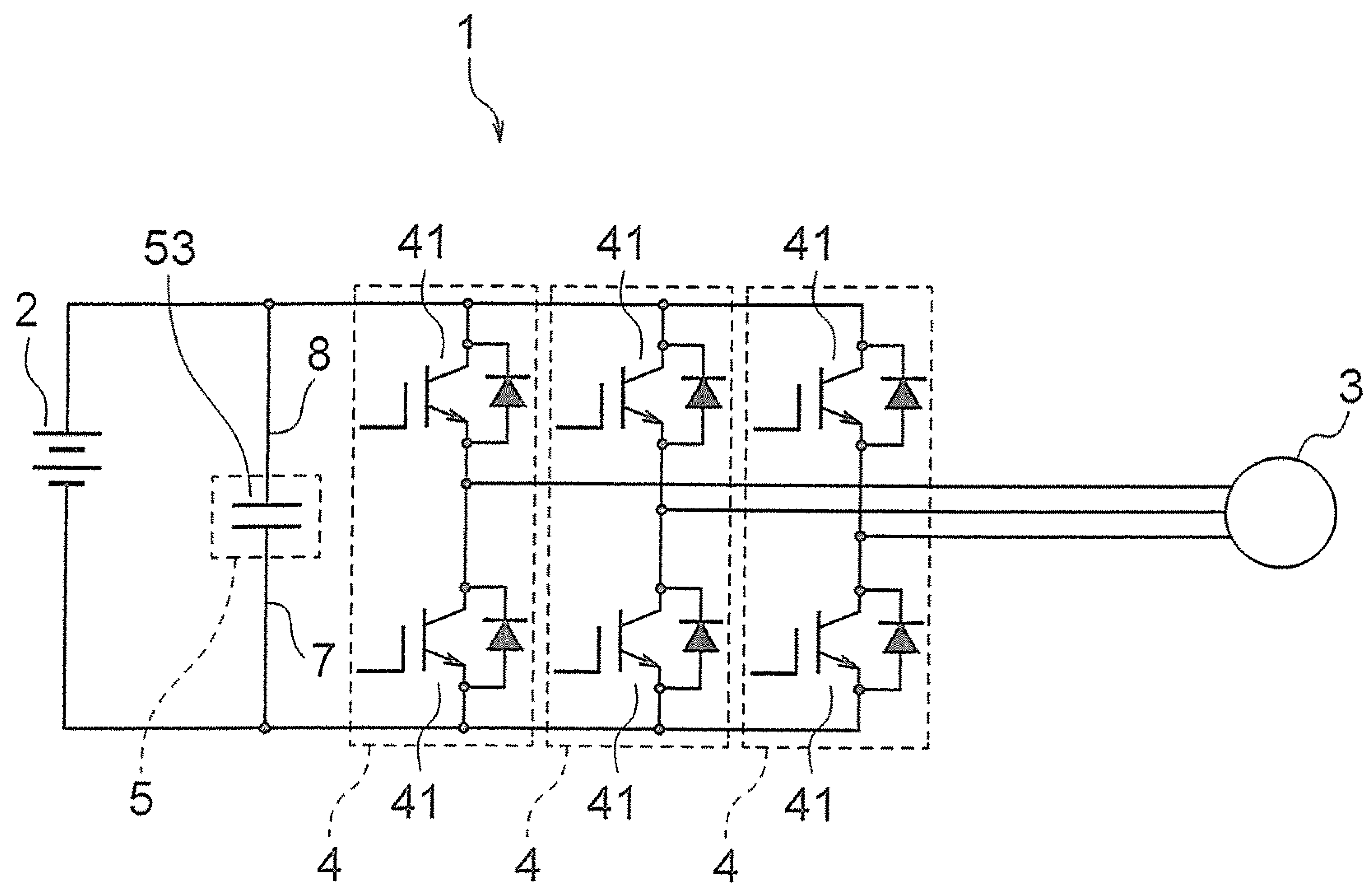
FIG. 1


1
53
2
8
41
41
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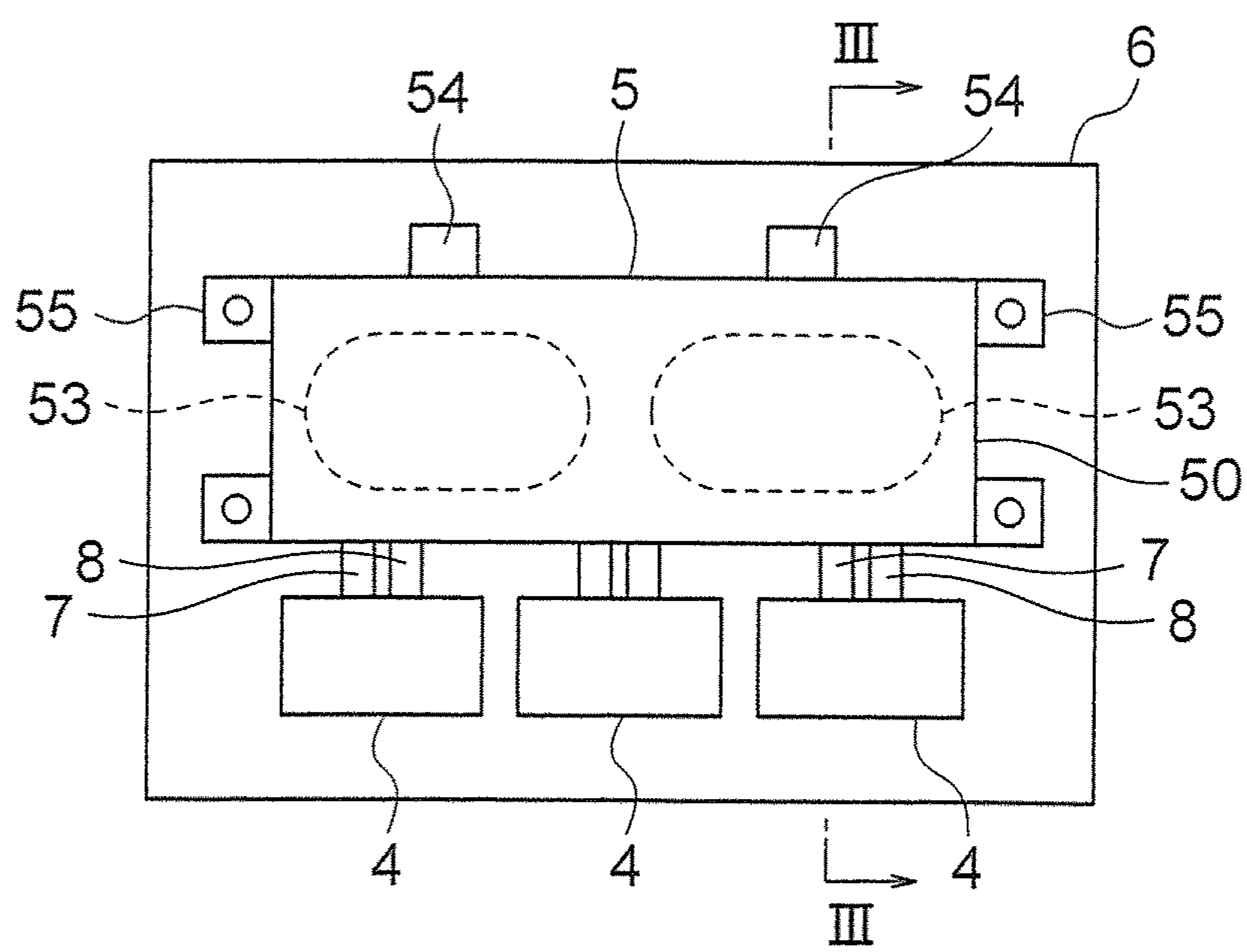
3
7
5
41
41
41
4
4
4

FIG. 2


III
54
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54
6
55
55
53
53
50
8
7
7
8
4
4
4
III

FIG. 3

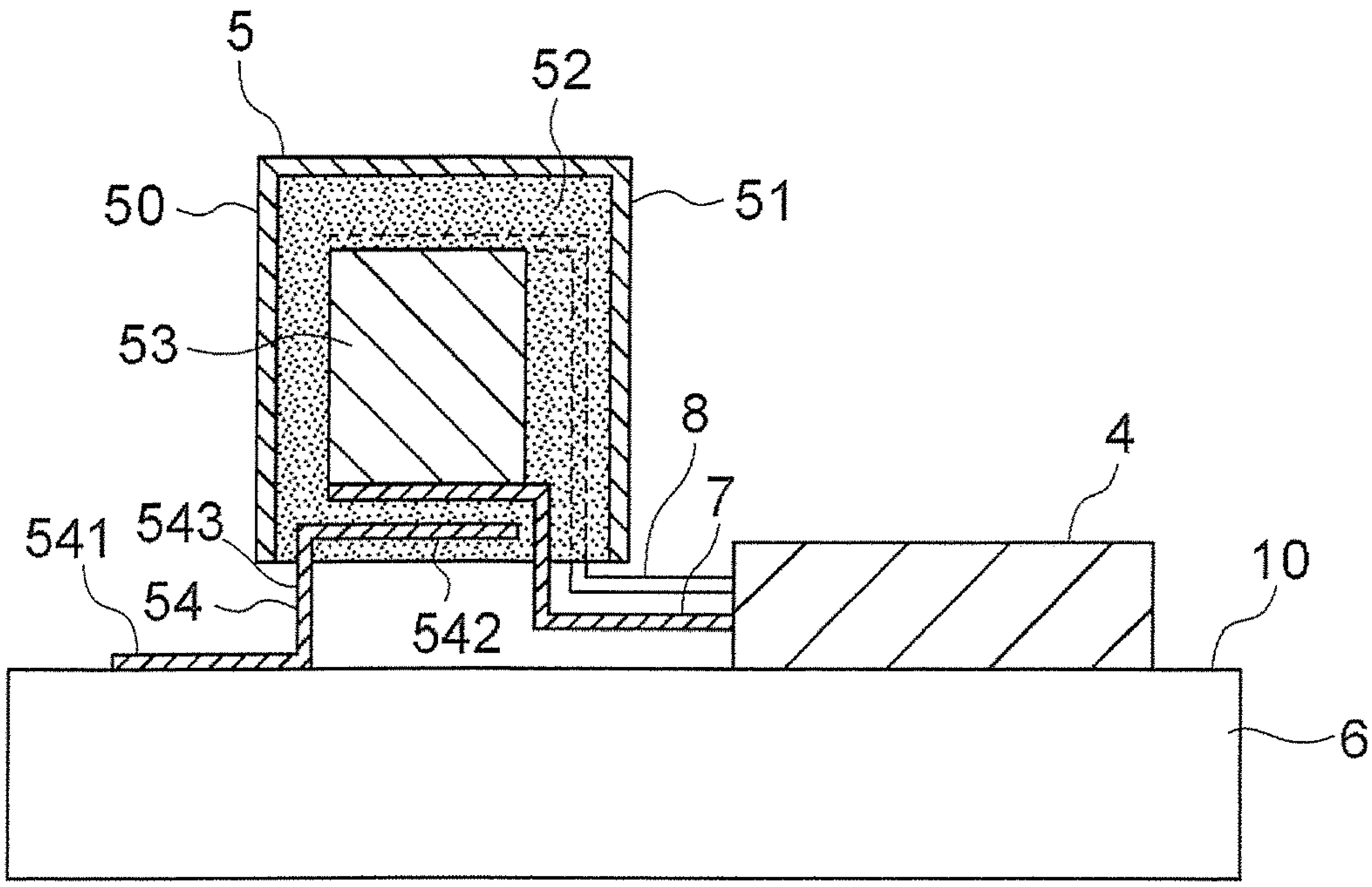

5
52
50
51
53
8
4
7
541
543
10
54
542
6

FIG. 4

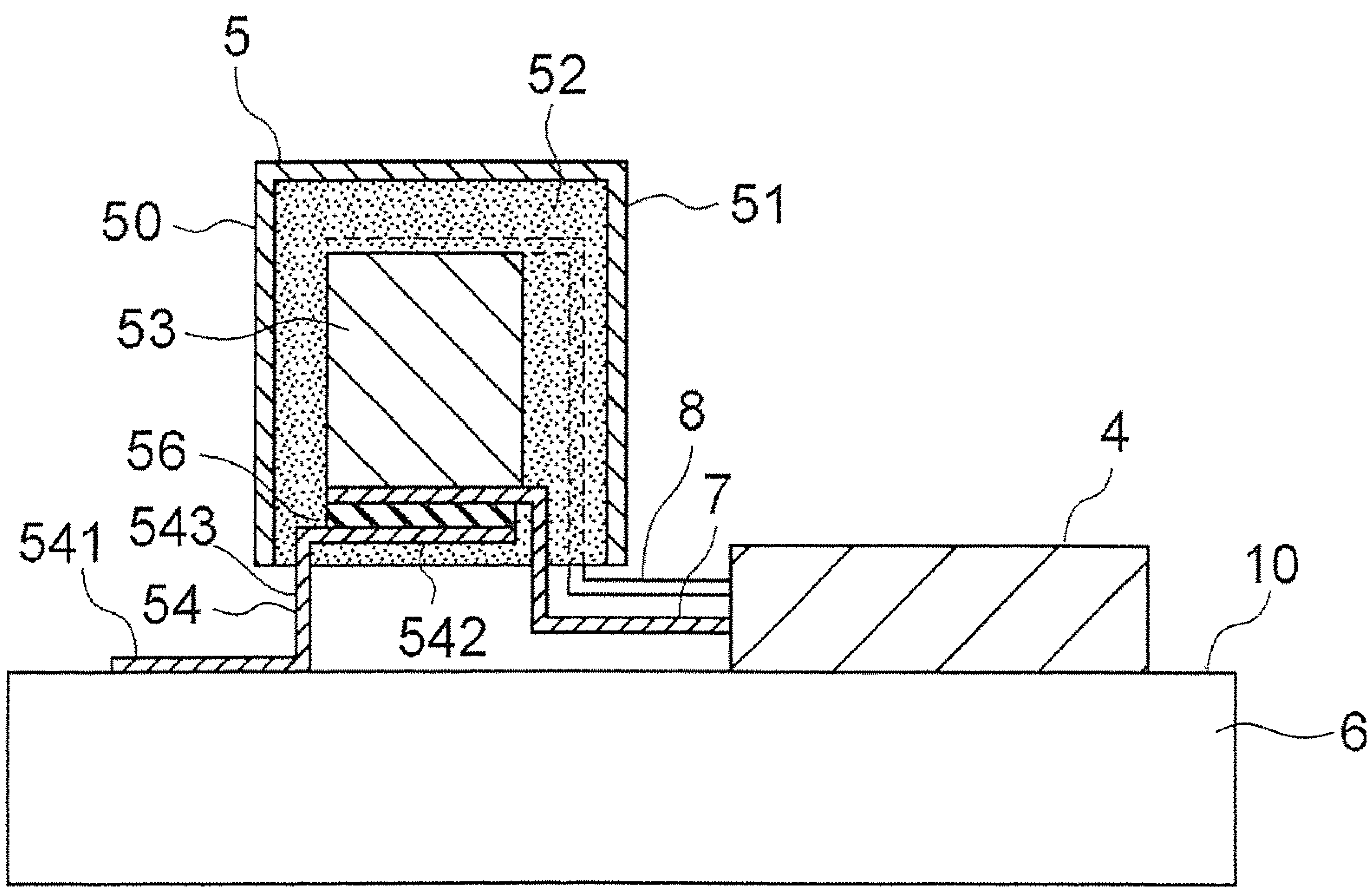

5
52
50
51
53
8
4
56
7
541
543
10
54
542
6

FIG. 5

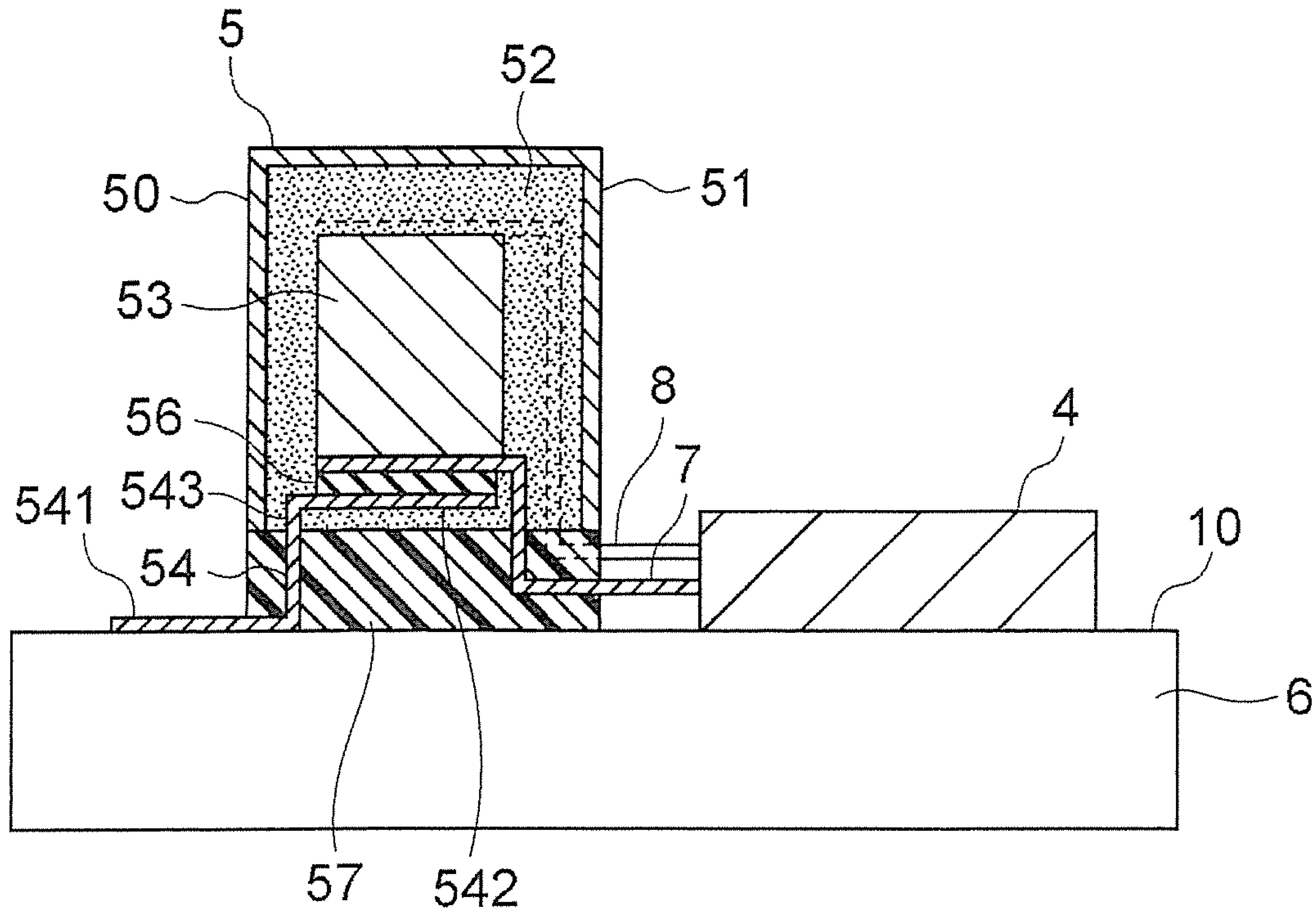

5
52
50
51
53
8
4
56
7
543
541
10
54
6
57
542

FIG. 6

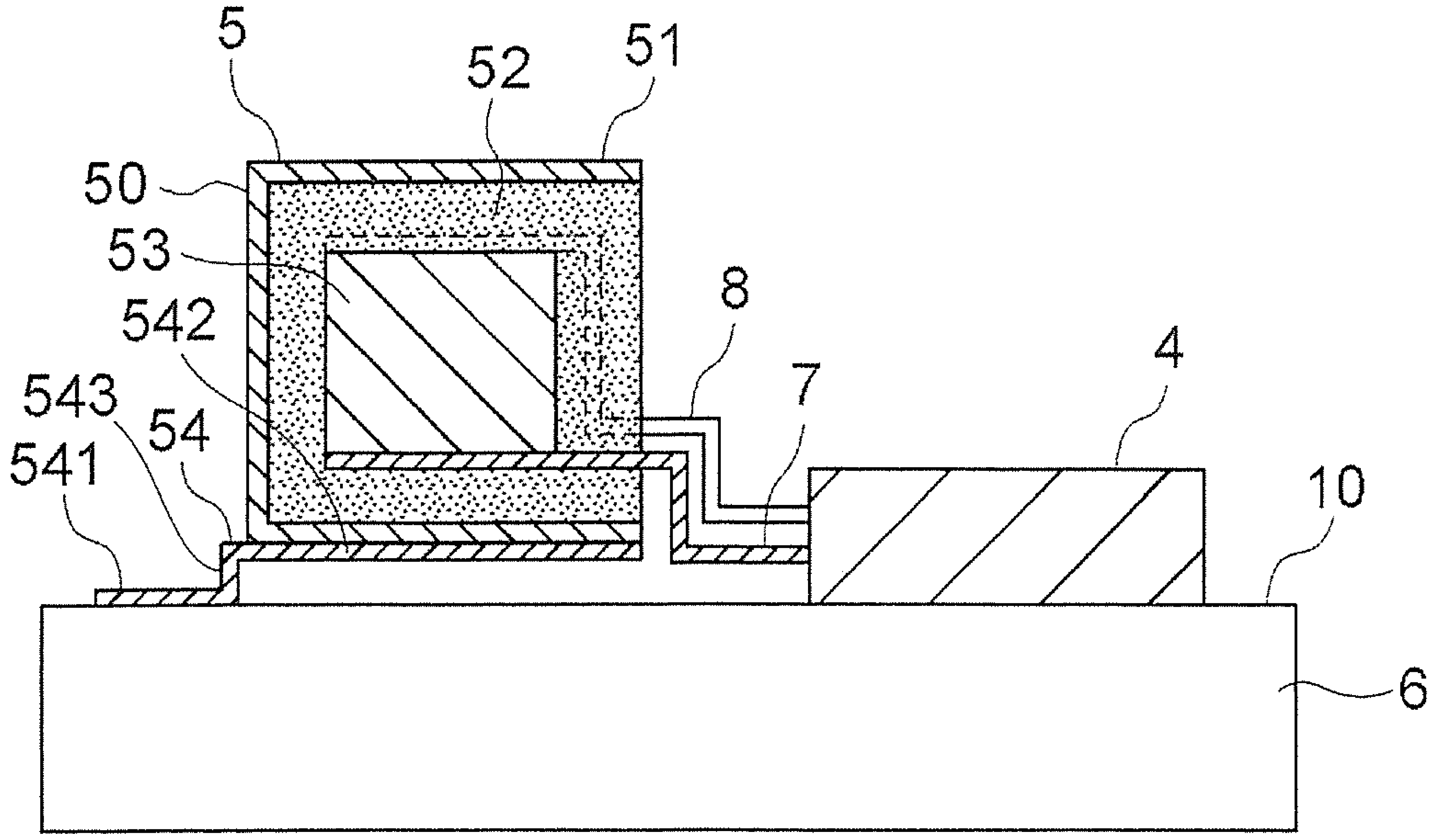

5
52
51
50
53
8
542
4
543
7
54
541
10
6

FIG. 7

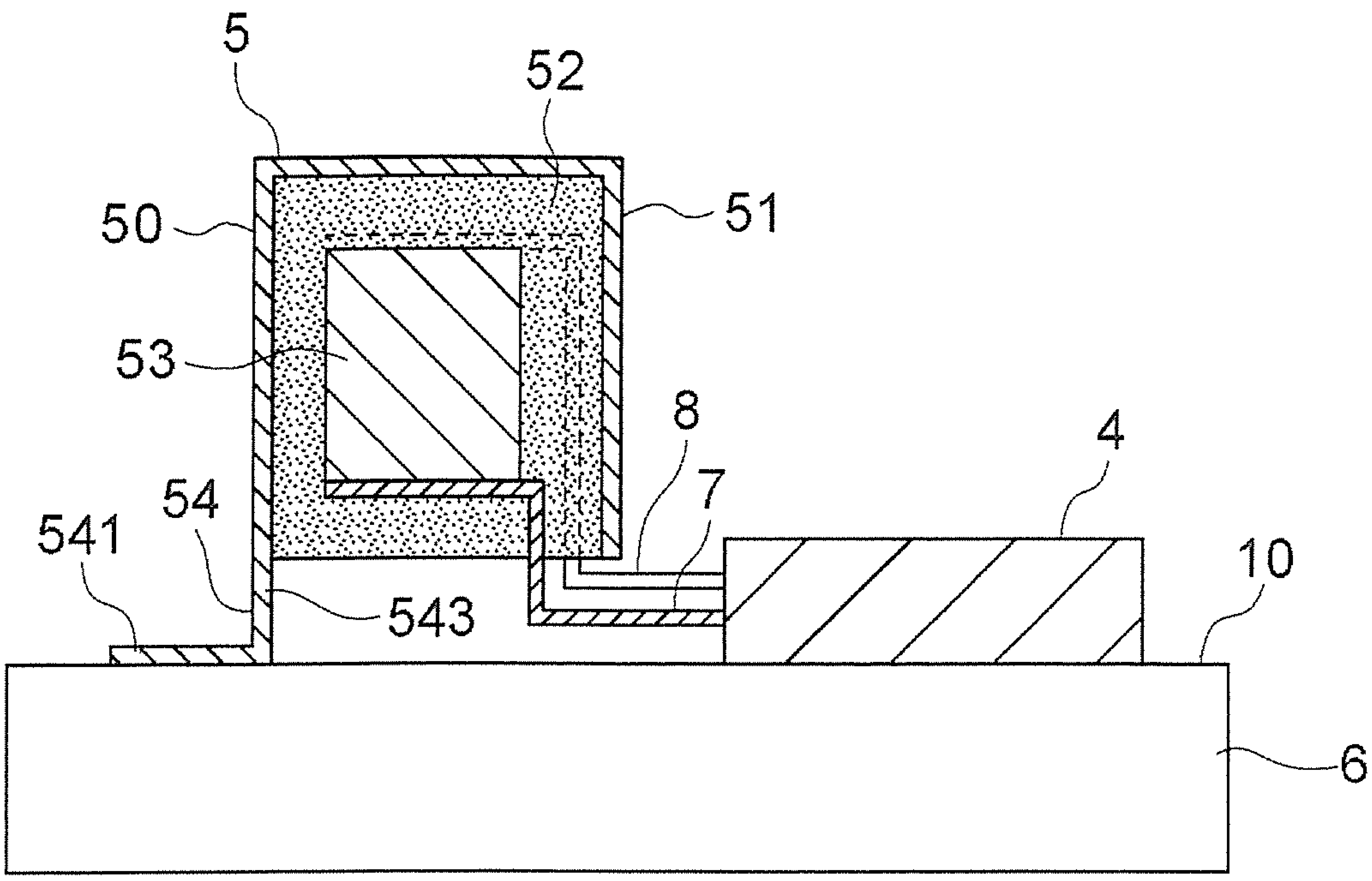
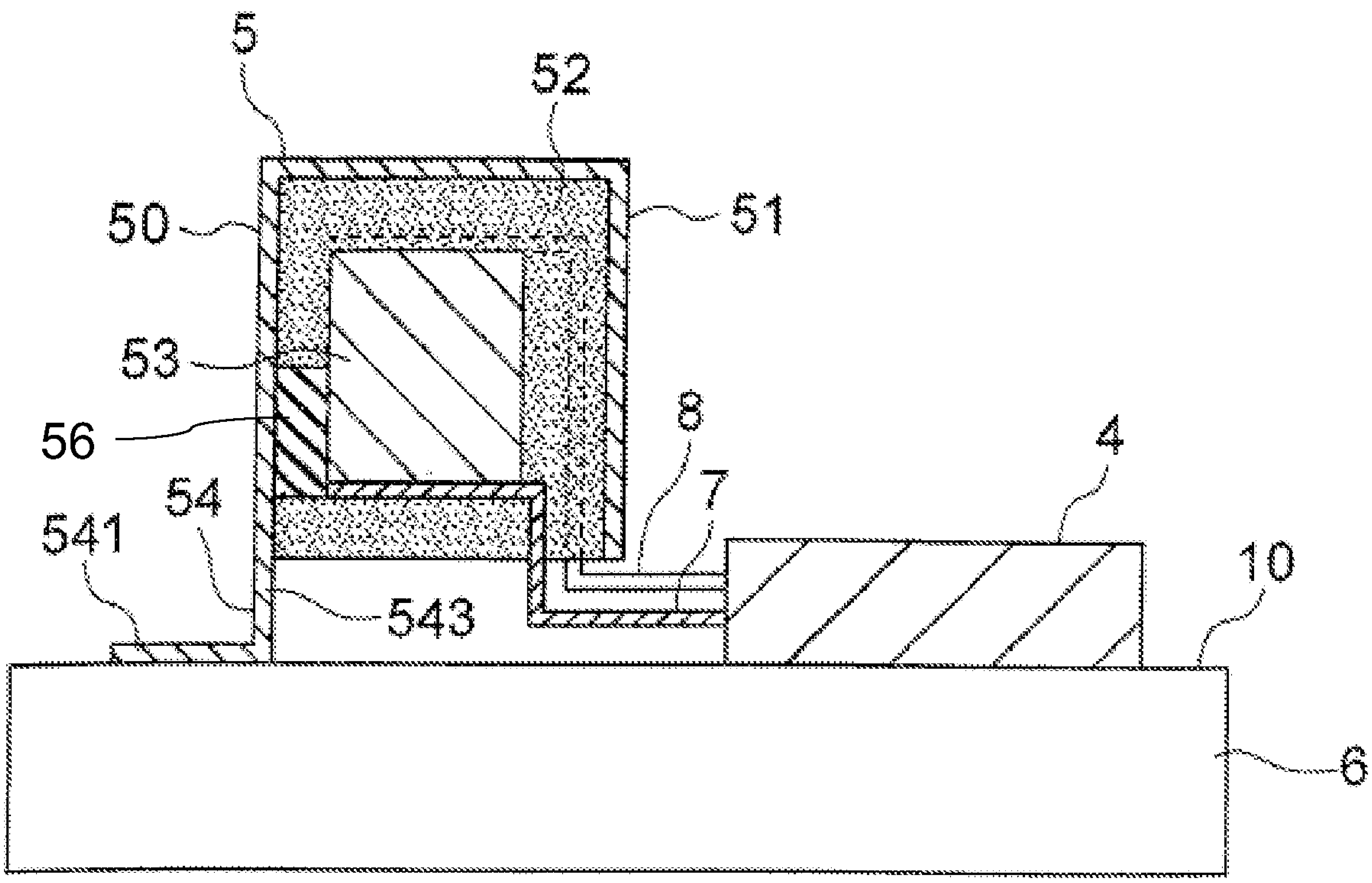


FIG. 8



POWER CONVERTER HAVING IMPROVED COOLING

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a power converter including a semiconductor module and a capacitor module.

Description of the Related Art

Hitherto, there has been known a power converter in which a semiconductor module as a heat generating component is connected to a capacitor module via a bus bar. In the related art power converter thus configured, heat generated in the semiconductor module is liable to be transferred to the capacitor module via the bus bar. Accordingly, in the related art power converter, a temperature of a capacitor element included in the capacitor module is liable to increase, and thus the capacitor module tends to have a shorter lifetime.

Meanwhile, there has hitherto been proposed a power converter in which, a shared cooler is attached to each of the semiconductor module and the capacitor module so as to suppress a temperature increase in each of a semiconductor module and a capacitor module (see, for example, Patent Literature 1).

CITATION LIST

Patent Literature

[PTL 1] JP 2013-146179 A

SUMMARY OF THE INVENTION

In a power converter, it is preferred to bring a position of a capacitor module closer to a position of a semiconductor module and reduce an inductance of a bus bar so as to improve performance of the power converter. However, in the related-art power converter disclosed in Japanese Patent Application Laid-Open No. 2013-146179, when the capacitor module is brought closer to the semiconductor module, the capacitor module is arranged within a range of the cooler in which a temperature is increased under the influence of heat generation from the semiconductor module. As a result, in the related-art power converter, the capacitor module is less likely to be cooled by the cooler.

The present invention has been achieved to solve a problem as described above. An object of the present invention is to provide a power converter capable of improving its performance, and also allowing each of a semiconductor module and a capacitor module to be more reliably cooled.

According to at least one embodiment of the present invention, there is provided a power converter including: a cooler having a cooling surface formed therein; a semiconductor module provided on the cooling surface; and a capacitor module including a capacitor module main body facing the cooling surface, while being apart from the cooling surface, and a heat conductive member provided in the capacitor module main body, the capacitor module main body being connected to the semiconductor module via a bus bar, the heat conductive member having a heat radiation portion, the heat radiation portion being thermally connected to the cooling surface at a position more distant from the

semiconductor module than an end portion of the capacitor module main body which is closer to the semiconductor module.

The power converter according to the at least one embodiment of the present invention is capable of improving its performance, and also allowing each of the semiconductor module and the capacitor module to be more reliably cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a circuit diagram for illustrating a power converter according to a first embodiment of the present invention;

FIG. **2** is a top view for illustrating the power converter of FIG. **1**;

FIG. **3** is a sectional view taken along the line of FIG. **2**;

FIG. **4** is a sectional view for illustrating a power converter according to a second embodiment of the present invention;

FIG. **5** is a sectional view for illustrating a power converter according to a third embodiment of the present invention;

FIG. **6** is a sectional view for illustrating a power converter according to a fourth embodiment of the present invention;

FIG. **7** is a sectional view for illustrating a power converter according to a fifth embodiment of the present invention; and

FIG. **8** is a sectional view for illustrating a power converter.

DESCRIPTION OF THE EMBODIMENTS

Referring to the drawings, embodiments of the present invention are described below.

First Embodiment

FIG. **1** is a circuit diagram for illustrating a power converter according to a first embodiment of the present invention. FIG. **2** is a top view for illustrating the power converter of FIG. **1**. FIG. **3** is a sectional view taken along the line III-III of FIG. **2**. A power converter **1** is configured to convert electric energy between a power source and a load. In this example, a vehicular power converter to be mounted in a vehicle, such as a hybrid vehicle or an electric vehicle, is used as the power converter **1**.

The power converter **1** includes a plurality of semiconductor modules **4**, a capacitor module **5**, and a cooler **6**. In this example, the three semiconductor modules **4** individually corresponding to three phases are included in the power converter **1**.

The capacitor module **5** is electrically connected to a battery **2** as a DC power source. A DC voltage from the battery **2** is smoothed by the capacitor module **5**.

For the capacitor module **5**, N-side bus bars **7** and P-side bus bars **8** are provided as a plurality of bus bars. Each of the N-side bus bars **7** and the P-side bus bars **8** is formed of a conductive material, for example, copper. The capacitor module is electrically connected individually to each of the semiconductor modules **4** via the N-side bus bar **7** and the P-side bus bar **8**. The capacitor module **5** is also thermally connected to each of the semiconductor modules **4** via the N-side bus bar **7** and the P-side bus bar **8**.

Each of the semiconductor modules **4** converts the DC voltage smoothed by the capacitor module **5** to an AC voltage. As illustrated in FIG. **1**, each of the semiconductor modules **4** includes a plurality of switching elements **41**. In this example, the two switching elements **41** connected in series to each other are included in each of the semiconductor modules **4**. Of the two switching elements **41** of the semiconductor module **4**, one is connected to the N-side bus bar **7** and another is connected to the P-side bus bar **8**.

Each of the switching elements **41** individually performs a switching operation under the control of a control device (not shown). Accordingly, each of the semiconductor modules **4** is a heat generating component that generates heat as a result of the switching operation performed by each of the switching elements **41**. The DC voltage smoothed by the capacitor module **5** is converted to a three-phase AC voltage by the switching operation performed by each of the switching elements **41**.

Each of the semiconductor modules **4** is electrically connected to a motor **3** serving as a load. The motor **3** operates with a supply of the three-phase AC voltage from each of the semiconductor modules **4** to the motor **3**.

The cooler **6** is configured to cool the semiconductor modules **4** and the capacitor module **5**. In the cooler **6**, as illustrated in FIG. **3**, a cooling surface **10** is formed. Further, in the cooler **6**, a flow path (not shown) in which a cooling medium flows is formed. The cooling medium enters the flow path of the cooler **6** from a flow path inlet of the cooler **6**. The cooling medium flowing through the flow path of the cooler **6** is discharged from a flow path outlet of the cooler **6** to the outside of the cooler **6**.

The cooling surface **10** is cooled by the cooling medium flowing through the cooler **6**. As the cooling medium, water, oil, air, or the like is used. In this example, an air-cooling cooler using air as the cooling medium is used as the cooler **6**.

The semiconductor modules **4** are provided on the cooling surface **10**. An outer surface of each of the semiconductor modules **4** has a portion in contact with the cooling surface **10**. Thus, each of the semiconductor modules **4** is thermally connected to the cooling surface **10**. Heat generated in the semiconductor module **4** is radiated to the cooling surface **10**. Thus, the semiconductor module **4** is cooled. The heat transferred to the cooling surface **10** is radiated into the cooling medium flowing in the cooler **6**.

The capacitor module **5** includes a capacitor module main body **50** and a plurality of heat conductive members **54** provided in the capacitor module main body **50**.

The capacitor module main body **50** is arranged apart from each of the semiconductor modules **4**. Further, the capacitor module main body **50** is electrically and thermally connected to each of the semiconductor modules **4** via the N-side bus bar **7** and the P-side bus bar **8**. Further, the capacitor module main body **50** is arranged apart from the cooling surface **10**. Further, the capacitor module main body **50** also faces the cooling surface **10**. As a result, between the capacitor module main body **50** and the cooling surface **10**, a space is formed.

The capacitor module main body **50** includes a capacitor case **51**, a plurality of capacitor elements **53** arranged in the capacitor case **51**, and a filling member **52** which is made of a resin, and covers the plurality of capacitor elements **53** in the capacitor case **51**.

As illustrated in FIG. **2**, the capacitor case **51** is provided with a plurality of fixed portions **55**. Each of the fixed portions **55** is fixed to the cooling surface **10**. With this, a state in which the capacitor module main body **50** is apart from the cooling surface **10** is maintained. When the power converter **1** is viewed along a direction perpendicular to the cooling surface **10**, a distance between each of the semiconductor modules **4** and each of the fixed portions **55** is larger than a distance between each of the semiconductor modules **4** and the capacitor module main body **50**.

In the capacitor case **51**, an opening is formed. In this example, the capacitor case **51** is arranged such that the opening thereof faces the cooling surface **10**. In addition, an outer surface of the capacitor case **51** is exposed to external air. The capacitor case **51** is formed of metal having heat transfer performance. A thermal conductivity of the capacitor case **51** is higher than a thermal conductivity of the filling member **52**.

Each of the N-side bus bars **7** and the P-side bus bars **8** is inserted into the capacitor case **51** through the opening of the capacitor case **51**. Further, each of the N-side bus bars **7** and the P-side bus bars **8** extends through the filling member **52** to be connected to the corresponding capacitor element **53**. Further, each of the N-side bus bars **7** and the P-side bus bars **8** is held in the capacitor case **51** via the filling member **52**.

The filling member **52** fills the inside of the capacitor case **51**. A part of each of the N-side bus bars **7**, a part of each of the P-side bus bars **8**, and each of the capacitor elements **53** are embedded in the filling member **52**. Thus, the filling member **52** seals each of the capacitor elements **53** in the capacitor case **51**. A resin as a material forming the filling member **52** is a material having heat transfer performance.

A part of heat generated in each of the semiconductor modules **4** is transferred through each of the N-side bus bar **7** and the P-side bus bar **8** and reaches the capacitor module main body **50**. The part of heat transferred from each of the semiconductor modules **4** and reaching the capacitor module main body **50** is transferred through the filling member **52** and radiated from the outer surface of the capacitor case **51** to the external air.

Each of the heat conductive members **54** is formed of a material having the heat transfer performance. In this example, each of the heat conductive members **54** is formed of metal, for example, copper. Each of the heat conductive members **54** has a heat conductivity higher than the heat conductivity of the filling member **52**. In this example, the heat conductive members **54** are arranged at positions away from each of the N-side bus bars **7**, the P-side bus bars **8**, the capacitor case **51**, and the capacitor elements **53**.

Each of the heat conductive members **54** has a plate-shaped heat radiation portion **541** in contact with the cooling surface **10**, a plate-shaped attachment portion **542** attached to the capacitor module main body **50**, and a joint portion **543** joining the heat radiation portion **541** to the attachment portion **542**.

The attachment portion **542** is arranged in the capacitor module main body **50**, while being embedded in the filling member **52**. With this, each of the heat conductive members **54** is held in the capacitor case **51** via the filling member **52**.

The joint portion **543** extends from the attachment portion **542** to the outside of the capacitor case **51** through the opening of the capacitor case **51**. The joint portion **543** also extends from the inside of the filling member **52** to the outside of the filling member **52** toward the cooling surface **10**. With this, heat in the capacitor module main body **50** is transferred to the outside of the capacitor module main body **50** through each of the attachment portion **542** and the joint portion **543**. The joint portion **543** is also joined to the heat radiation portion **541** at the cooling surface **10**.

The heat radiation portion **541** is arranged at a position away from the capacitor module main body **50**. The heat radiation portion **541** is also in contact with the cooling surface **10** to be thermally connected to the cooling surface

10. With this, the heat in the capacitor module main body **50** is radiated to the cooling surface **10** through each of the heat conductive members **54**.

Further, the heat radiation portion **541** is in contact with the cooling surface **10** at a position distant from each of the semiconductor modules **4** than an end portion of the capacitor module main body **50** which is closer to the semiconductor module **4**. In other words, when the power converter **1** is viewed along a direction perpendicular to the cooling surface **10**, a distance between each of the semiconductor modules **4** and the heat radiation portion **541** is longer than a distance between each of the semiconductor modules **4** and the capacitor module main body **50**.

Further, the heat radiation portion **541** extends from the joint portion **543** to the opposite side of each of the semiconductor modules **4** along the cooling surface **10**. Consequently, the heat radiation portion **541** has a portion reaching a position more distant from the semiconductor module **4** than a region of the cooling surface **10** facing the capacitor module main body **50**. In other words, when the power converter **1** is viewed along the direction perpendicular to the cooling surface **10**, the heat radiation portion **541** has a portion protruding from the region of the capacitor module main body **50** to the opposite side of the semiconductor module **4**, as illustrated in FIG. **2**.

The capacitor module main body **50** and each of the semiconductor modules **4** are arranged in a direction of the flow of the cooling medium flowing in the cooler **6**. The heat radiation portion **541** is in contact with the cooling surface **10** at a position upstream of a position of the corresponding semiconductor module **4** in the flow of the cooling medium. In other words, the heat radiation portion **541** is in contact with the cooling surface **10** at the position closer to the flow path inlet of the cooler **6** than the position of the corresponding semiconductor module **4**. Accordingly, the cooling medium flowing in the cooler **6** absorbs heat from the heat radiation portion **541** and then absorbs heat from the corresponding semiconductor module **4**.

When a length of each of the N-side bus bars **7** and the P-side bus bars **8** is reduced by bringing the capacitor module main body **50** closer to each of the semiconductor modules **4**, an inductance of each of the N-side bus bars **7** and the P-side bus bars **8** is reduced. With this, performance of the power converter **1** is improved. Accordingly, it is preferred that the position of the capacitor module main body **50** be closest to each of the semiconductor modules **4**.

On the other hand, around each of the semiconductor modules **4**, a temperature of the cooling surface **10** is increased by the heat generated in each semiconductor module **4**. In particular, when an air-cooling cooler having a low cooling ability is used as the cooler **6**, the temperature of the cooling surface **10** tends to be increased around each of the semiconductor modules **4**. Accordingly, when the capacitor module main body **50** is brought into contact with the cooling surface **10** at a position close to each of the semiconductor modules **4**, the capacitor module main body **50** comes into contact with the cooling surface **10** having the increased temperature. In this case, heat cannot be efficiently radiated from the capacitor module main body **50** to the cooling surface **10**.

However, in the power converter **1** according to the first embodiment, the capacitor module main body **50** is away from the cooling surface **10**. Accordingly, it is possible to prevent the transfer of heat generated in each of the semiconductor modules **4** to the capacitor module main body **50** via the cooling surface **10**. With this, the position of the capacitor module main body **50** can be brought closer to each of the semiconductor modules **4**. Therefore, it is possible to reduce the inductance of each of the N-side bus bars **7** and the P-side bus bars **8** and improve the performance of the power converter **1**.

In addition, the heat radiation portion **541** is in contact with the cooling surface **10** at the position more distant from each of the semiconductor modules **4** than the end portion of the capacitor module main body **50** closer to the semiconductor module **4**. Thus, the heat radiation portion **541** can be brought into contact with the cooling surface **10** at a position at which the cooling surface **10** is less likely to be affected by the heat from each of the semiconductor modules **4**. As a result, it is possible to efficiently dissipate the heat in the capacitor module main body **50** from the heat radiation portion **541** to the cooling surface **10**. Therefore, it is possible to more reliably cool not only each of the semiconductor modules **4**, but also the capacitor module **5**.

Moreover, the heat radiation portion **541** is in contact with the cooling surface **10** at the position upstream of the position of each of the semiconductor modules **4** in the flow of the cooling medium cooling the cooling surface **10**. With this, the heat radiation portion **541** can be brought into contact with the cooling surface **10** at a position at which the cooling medium flows before absorbing heat from each of the semiconductor modules **4**. Consequently, it is possible to maintain the cooling surface **10** at a position at which the heat radiation portion **541** is in contact therewith in a low temperature state and allow the heat in the capacitor module main body **50** to be more efficiently radiated from the heat radiation portion **541** to the cooling surface **10**. Therefore, it is possible to more reliably cool the capacitor module **5**.

Each of the heat conductive members **54** has the attachment portion **542** arranged in the capacitor module main body **50**. Accordingly, it is possible to efficiently transfer heat in the capacitor module main body **50** to the outside of the capacitor module main body **50** through the heat conductive members **54**. With this, the capacitor module **5** can be more reliably cooled. In addition, the heat conductive members **54** can be integrated with the capacitor module main body **50**. Consequently, upon manufacturing the power converter **1**, it is possible to handle the capacitor module main body **50** and the heat conductive members **54** as one component. This can facilitate an operation of manufacturing the power converter **1**.

Each of the N-side bus bars **7** and the P-side bus bars **8** is connected to the capacitor element **53** through the filling member **52**. In addition, each of the N-side bus bars **7** and the P-side bus bars **8** is also held in the capacitor case **51** via the filling member **52**. Accordingly, it is possible to allow the filling member **52** to transfer, to the capacitor case **51**, a part of the heat that has been transferred from each of the semiconductor modules **4** through the N-side bus bar **7** and the P-side bus bar **8** and has reached the capacitor module main body **50**. Thus, it is possible to dissipate the heat from the capacitor case **51** to the external air and more reliably suppress a temperature increase in the capacitor module **5**.

Second Embodiment

FIG. **4** is a sectional view for illustrating a power converter according to a second embodiment of the present invention. Between each of the N-side bus bars **7** and the attachment portion **542**, an insulating paper sheet **56** as an insulating member different from the filling member **52** is interposed. As a result, the attachment portion **542** of each of the heat conductive members **54** is arranged under the N-side bus bar **7** via the insulating paper sheet **56** in the capacitor case **51**. The insulating paper sheet **56** has a heat conductivity higher than the heat conductivity of the filling member **52**. The insulating paper sheet **56** is an insulating member having electrical insulation performance. The electrical insulation performance of the insulating paper sheet **56** is higher than electrical insulation performance of the filling member **52**.

A part of the heat transferred to each of the N-side bus bars **7** is transferred to the attachment portion **542** via the insulating paper sheet **56**. The heat transferred from the N-side bus bar **7** to the attachment portion **542** is radiated to the cooling surface **10** through each of the joint portion **543** and the heat radiation portion **541**. Other configurations are the same as those of the first embodiment.

In the power converter **1** thus configured, the insulating paper sheet **56** having the heat conductivity higher than that of the filling member **52** is interposed between the attachment portion **542** of each of the heat conductive members **54** and the corresponding N-side bus bar **7**. This allows easier heat transfer from the N-side bus bar **7** to the heat conductive member **54**. Therefore, it is possible to more efficiently dissipate the heat in the capacitor module main body **50** to the cooling surface **10**.

In the example described above, as the insulating member interposed between the attachment portion **542** and the N-side bus bar **7**, the insulating paper sheet **56** is used. However, the insulating member interposed between the attachment portion **542** and the N-side bus bar **7** is not required to be the insulating paper sheet **56** as long as the insulating member has the heat conductivity higher than that of the filling member **52**. Accordingly, a heat conductive sheet made of a resin, a ceramic plate, or the like may also be used as the insulating member.

Further, in the example described above, the insulating paper sheet **56** is interposed between the attachment portion **542** and the N-side bus bar **7**. However, it is also possible, as illustrated in FIG. **8**, to dispose the attachment portion **542** in the capacitor case **51** such that the attachment portion **542** faces the corresponding P-type bus bar **8**, and to interpose the insulating paper sheet **56** between the attachment portion **542** and the P-side bus bar **8**. Alternatively, it is also possible, as illustrated in FIG. **8**, to dispose the attachment portion **542** in the capacitor case **51** such that the attachment portion **542** faces the corresponding capacitor element **53**, and to interpose the insulating paper sheet **56** between the attachment portion **542** and the capacitor element **53**. Such configurations also allow the heat in the capacitor module main body **50** to be more efficiently dissipated to the cooling surface **10**. By thus interposing the insulating paper sheet **56** between the attachment portion **542** and at least any one of the N-side bus bar **7**, the P-side bus bar **8**, and the capacitor element **53**, it is possible to more efficiently dissipate the heat in the capacitor module main body **50** to the cooling surface **10**.

Third Embodiment

FIG. **5** is a sectional view for illustrating a power converter according to a third embodiment of the present invention. Between the capacitor module main body **50** and the cooling surface **10**, a heat insulating member **57** is interposed. In addition, the capacitor module main body **50** is supported by the cooling surface **10** via the heat insulating member **57**.

The heat insulating member **57** is formed of a material having a heat conductivity lower than that of the capacitor module main body **50**. In other words, the heat insulating member **57** is formed of a material having a heat conductivity lower than those of the capacitor case **51**, the filling member **52**, and the capacitor elements **53**. As the material forming the heat insulating member **57**, a resin, rubber, or the like is used. Other configurations are the same as those of the second embodiment.

In the power converter **1** thus configured, the heat insulating member **57** formed of the material having the heat conductivity lower than that of the capacitor module main body **50** is interposed between the capacitor module main body **50** and the cooling surface **10**. With this, the heat insulating member **57** can more reliably suppress heat transfer from the cooling surface **10** to the capacitor module main body **50**. Consequently, each of the semiconductor modules **4** and the capacitor module **5** can more reliably be cooled. This also allows the heat insulating member **57** to stably support the capacitor module main body **50** with respect to the cooling surface **10**. As a result, it is possible to improve anti-vibration performance of the power converter **1**, and prevent occurrence of a failure in the power converter **1**.

Fourth Embodiment

FIG. **6** is a sectional view for illustrating a power converter according to a fourth embodiment of the present invention. The attachment portion **542** of each of the heat conductive members **54** is attached to an outer surface of the capacitor module main body **50**. The attachment portion **542** is also in contact with the outer surface of the capacitor module main body **50**. Through the contact with the outer surface of the capacitor module main body **50**, the attachment portion **542** is thermally connected to the outer surface of the capacitor module main body **50**. In this example, the attachment portion **542** is in contact with the outer surface of the capacitor case **51**. Accordingly, in this example, the heat conductive members **54** are not inserted into the capacitor module main body **50**.

The capacitor case **51** is arranged with the opening thereof facing each of the semiconductor modules **4**. Consequently, the outer surface of the capacitor case **51** has a portion facing the cooling surface **10**.

Each of the attachment portions **542** is attached to a part of the outer surface of the capacitor case **51** facing the cooling surface **10**. The heat in the capacitor module main body **50** is radiated from the capacitor case **51** to the cooling surface **10** through the heat conductive members **54**. Other configurations are the same as those of the first embodiment.

Even when the attachment portion **542** of each of the heat conductive members **54** is thus attached to the outer surface of the capacitor module main body **50**, it is possible to allow the heat in the capacitor module main body **50** to be efficiently transferred to the heat conductive member **54**. With this, the capacitor module main body **50** can be more reliably cooled.

In the example described above, each of the attachment portions **542** is in contact with the outer surface of the capacitor module main body **50**. However, the attachment portion **542** may be also attached to the outer surface of the capacitor module main body **50** via an adhesive member having heat transfer performance. In this case, the adhesive member is in close contact with each of the outer surface of the capacitor module main body **50** and the attachment portion **542** with no gap formed therebetween. Further, in this case, the attachment portion **542** is attached to the outer surface of the capacitor module main body **50** via the adhesive member to be thermally connected to the outer surface of the capacitor module main body **50**. As the adhesive member, heat-radiation grease, a heat conductive sheet made of a resin, or the like is used. It is preferred that the adhesive member have a heat conductivity higher than the respective heat conductivities of the capacitor case **51** and the heat conductive members **54**. However, the heat conductivity of the adhesive member may be the same as or lower than the respective heat conductivities of the capacitor case **51** and the heat conductive members **54**. With this, a gap formed between the outer surface of the capacitor module main body **50** and each of the attachment portions **542** can be filled with the adhesive member, and the heat in the capacitor module main body can be more efficiently transferred to each of the heat conductive members **54**. As a result, it is possible to more reliably cool the capacitor module main body **50**.

In the example described above, the capacitor module main body **50** is arranged with the opening of the capacitor case **51** facing each of the semiconductor modules **4**. However, the opening of the capacitor case **51** may also face the cooling surface **10**.

Fifth Embodiment

FIG. **7** is a sectional view for illustrating a power converter according to a fifth embodiment of the present invention. Each of the heat conductive members **54** is formed integrally with the capacitor case **51**. In addition, the capacitor case **51** is formed of the same material as that of the heat conductive members **54**. Specifically, a single member has a portion serving as the capacitor case **51** and another portion serving as the heat conductive members **54**. As a material for forming the capacitor case **51** and the heat conductive member **54**, metal having high heat transfer performance, for example, aluminum, is used. The member in which the capacitor case **51** and the heat conductive members **54** are integrated has a heat conductivity higher than the heat conductivity of the filling member **52**.

Each of the heat conductive members **54** protrudes from an edge portion of the opening of the capacitor case **51** toward the cooling surface **10**. The heat conductive member **54** has the plate-shaped heat radiation portion **541** in contact with the cooling surface **10** and the joint portion **543** joining the heat radiation portion **541** to the capacitor case **51**. The respective configurations of the heat radiation portion **541** and the joint portion **543** are the same as those in the first embodiment. Other configurations are also the same as those of the first embodiment.

In the power converter **1** thus configured, the heat conductive members **54** are formed integrally with the capacitor case **51**. Accordingly, it is possible to handle the capacitor case **51** and the heat conductive members **54** as one component and reduce the number of the components. This can facilitate the operation of manufacturing the power converter **1**.

In the example described above, between the capacitor case **51** and each of the N-side bus bar **7**, the P-side bus bar **8**, and the capacitor element **53**, the filling member **52** is interposed. However, as shown in FIG. **8**, it is also possible to interpose an insulating member different from the filling member **52** between the capacitor case **51** and at least any one of the N-side bus bar **7**, the P-side bus bar **8**, and the capacitor element **53**. In this case, a member having a heat conductivity higher than that of the filling member **52** is used as the insulating member. Further, in this case, the member having electric insulation performance higher than that of the filling member **52** is used as the insulating member. As the insulating member, an insulating paper sheet **56**, a heat conductive sheet made of a resin, a ceramic plate, or the like is used. This allows easy heat transfer from at least any one of the N-side bus bar **7**, the P-side bus bar **8**, and the capacitor element **53** to the capacitor case **51** and to the heat conductive member **54**. Accordingly, it is possible to more efficiently dissipate the heat in the capacitor module main body **50** to the cooling surface **10**.

The third embodiment is obtained by applying the heat insulating member **57** to the power converter **1** of the second embodiment. However, it is also possible to apply the heat insulating member **57** to the power converter **1** of the first, fourth, or fifth embodiment.

In each of the embodiments described above, the heat radiation portion **541** is in contact with the cooling surface **10**. However, the heat radiation portion **541** may also be arranged over the cooling surface **10** via a heat conductive material having heat transfer performance. In this case, the heat radiation portion **541** is thermally connected to the cooling surface **10** via the heat conductive material. Further, in this case, the heat conductive material is interposed between the heat radiation portion **541** and the cooling surface **10**, while being in close contact with each of the heat radiation portion **541** and the cooling surface **10** with no gap formed therebetween. As the heat conductive material, heat-radiation grease, a heat conductive sheet made of a resin, or the like is used. It is preferred that the heat conductive material have a heat conductivity higher than that of each of the heat conductive members **54**. However, the heat conductivity of the heat conductive material may also be the same as or lower than the heat conductivity of each of the heat conductive members **54**. By thus setting the heat conductivity of the heat conductive material, it is possible to fill a gap formed between the heat radiation portion **541** and the cooling surface **10** with the heat conductive material, and allow the heat from the heat radiation portion **541** to be more efficiently transferred to the cooling surface **10**. As a result, it is possible to more efficiently dissipate the heat in the capacitor module main body **50** to the cooling surface **10**.

Further, in each of the embodiments described above, the heat radiation portion **541** is thermally connected to the cooling surface **10** at a position upstream of the position of the corresponding semiconductor module **4** in the flow of the cooling medium. However, the position of the heat radiation portion **541** is not limited to the position upstream of the position of the corresponding semiconductor module **4** in the flow of the cooling medium. For example, it is also possible to thermally connect the heat radiation portion **541** to the cooling surface **10** at a position displaced from the position of the corresponding semiconductor module **4** in a direction perpendicular to a direction of the flow of the cooling medium.

Further, in each of the embodiments described above, the heat radiation portion **541** has a portion arranged at a position more distant from each of the semiconductor modules **4** than the region of the cooling surface **10** facing the capacitor module main body **50**. However, it is also possible to dispose the whole heat radiation portion **541** at a position more distant from each of the semiconductor modules **4** than the region of the cooling surface **10** facing the capacitor module main body **50**.

What is claimed is:

1. A power converter comprising:

a cooler having a cooling surface formed therein;

a semiconductor module provided on the cooling surface; and

a capacitor module including:

a capacitor module main body facing the cooling surface at a distance from the cooling surface and connected to the semiconductor module via a bus bar, and

a heat conductive member connected to the capacitor module main body and having a heat radiation portion thermally connected to the cooling surface at a position more distant from the semiconductor module than an end portion of the capacitor module main body that is closest to the semiconductor module,

wherein:

the heat radiation portion is the only portion of the heat conductive member that is directly in contact with the cooling surface, and an entire length of the heat radiation portion is thermally connected to the cooling surface,

the capacitor module main body includes a capacitor case, a capacitor element arranged in the capacitor case, and a filling member which is made of a resin, and covers the capacitor element in the capacitor case;

the bus bar extends through the filling member to be connected to the capacitor element, while being held in the capacitor case via the filling member

wherein:

the capacitor case is formed of the same material as that of the heat conductive member; and

the heat conductive member is integral with the capacitor case

wherein, between the capacitor case and at least one of the capacitor element and the bus bar, an insulating member having a heat conductivity higher than that of the filling member is interposed.

2. A power converter comprising:

a cooler having a cooling surface formed therein;

a semiconductor module provided on the cooling surface; and

a capacitor module including:

a capacitor module main body facing the cooling surface at a distance from the cooling surface and connected to the semiconductor module via a bus bar, and

a heat conductive member connected to the capacitor module main body and having a heat radiation portion thermally connected to the cooling surface at a position more distant from the semiconductor module than an end portion of the capacitor module main body that is closest to the semiconductor module,

wherein:

the heat radiation portion is the only portion of the heat conductive member that is directly in contact with the cooling surface, and an entire length of the heat radiation portion is thermally connected to the cooling surface,

the capacitor module main body includes a capacitor case, a capacitor element arranged in the capacitor case, and a filling member which is made of a resin, and covers the capacitor element in the capacitor case;

the bus bar extends through the filling member to be connected to the capacitor element, while being held in the capacitor case via the filling member

wherein:

the heat conductive member has an attachment portion arranged inside the filling member; and

between the attachment portion and at least one of the capacitor element and the bus bar, an insulating member having a heat conductivity higher than that of the filling member is interposed.

3. The power converter according to claim **2**, wherein:

the cooling surface is cooled by a cooling medium flowing in the cooler; and

the heat radiation portion is thermally connected to the cooling surface at a position upstream of a position of the semiconductor module in a flow of the cooling medium.

4. The power converter according to claim **2**, wherein, between the capacitor module main body and the cooling surface, a heat insulating member formed of a material having a heat conductivity lower than that of the capacitor module main body is interposed.

5. The power converter according to claim **2**, wherein the heat conductive member has an attachment portion arranged inside the capacitor module main body.

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